

EXHIBIT 1



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Nowell et al.

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(54) **SEALING HIGH PRESSURE FLOW DEVICES**

(71) Applicant: **Kerr Machine Co.**, Sulphur, OK (US)

(72) Inventors: **Mark S. Nowell**, Ardmore, OK (US);
Kelcy Jake Foster, Ardmore, OK (US);
Michael Eugene May, Ardmore, OK (US);
Brandon Scott Ayres, Ardmore, OK (US);
Christopher Todd Barnett, Stratford, OK (US);
Michael Cole Thomas, Ardmore, OK (US);
Guy J. Lapointe, Sulphur, OK (US)

(73) Assignee: **Kerr Machine Co.**, Sulphur, OK (US)

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F16K 5/18 (2006.01)
F15B 7/06 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **F16K 5/184** (2013.01); **F04B 53/164**
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(Continued)

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CPC F16K 5/184; F16K 5/0492; F16K 5/0471;
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(Continued)

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Fluid end assemblies like those disclosed in Figure 11 of the current application and Figure 11 of the parent application, U.S. Patent Publication No. 2017/0089473, were offered for sale in the United States more than 1 year prior to Sep. 28, 2017.

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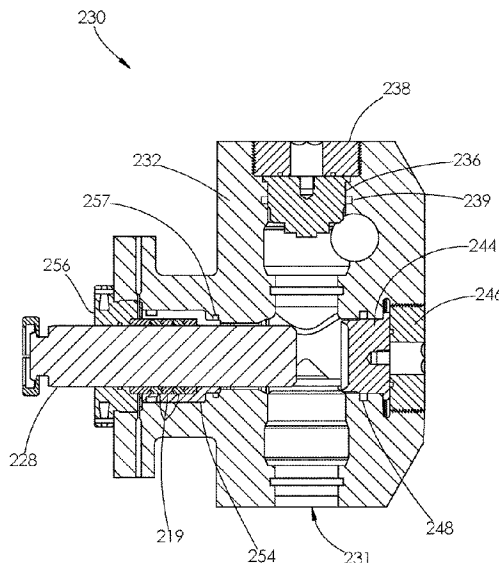
Primary Examiner — John Bastianelli

(74) *Attorney, Agent, or Firm* — Tomlinson McKinsty, P.C.

(57) **ABSTRACT**

Apparatus and method contemplating a high pressure fluid end assembly having a body defining a body bore and defining a recess in the body intersecting the body bore. A closure is joined to the body and forms a sealing surface. A seal is mounted to the body in the recess and configured to extend from the recess beyond the body bore to seal against the sealing surface formed by the closure.

24 Claims, 17 Drawing Sheets



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Related U.S. Application Data

application No. 15/280,642, filed on Sep. 29, 2016, now Pat. No. 10,288,178.

- (60) Provisional application No. 62/346,915, filed on Jun. 7, 2016, provisional application No. 62/318,542, filed on Apr. 5, 2016, provisional application No. 62/315,343, filed on Mar. 30, 2016, provisional application No. 62/234,483, filed on Sep. 29, 2015.

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F16K 5/04 (2006.01)
F16J 15/06 (2006.01)
F15B 21/00 (2006.01)
F16K 5/16 (2006.01)
F16K 5/02 (2006.01)
F04B 53/22 (2006.01)
F04B 53/16 (2006.01)

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CPC **F15B 21/00** (2013.01); **F16J 15/062** (2013.01); **F16K 5/0271** (2013.01); **F16K 5/0464** (2013.01); **F16K 5/0471** (2013.01); **F16K 5/0485** (2013.01); **F16K 5/0492** (2013.01); **F16K 5/161** (2013.01); **F16K 5/181** (2013.01)

(58) **Field of Classification Search**

CPC F16K 5/181; F16K 5/0271; F15B 7/06; F15B 21/00; F16J 15/062; F04B 53/22; F04B 53/164; F04B 53/162; F04B 53/16
USPC 251/366–367, 359, 360, 363, 214; 417/454

See application file for complete search history.

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Exhibit "A" includes cross-sectional views of fluid end assemblies known in the art prior to Sep. 29, 2015. 4 pages.

Exhibit "B" includes side views of valve seats known in the art prior to Sep. 29, 2015. 2 pages.

Exhibit "C" is a cross-sectional view of a plunger end of a fluid assembly known in the art prior to Sep. 29, 2015. 1 page.

Exhibit "D" includes an engineering drawing and pictures of a mud pump known in the art prior to Sep. 29, 2015. 4 pages.

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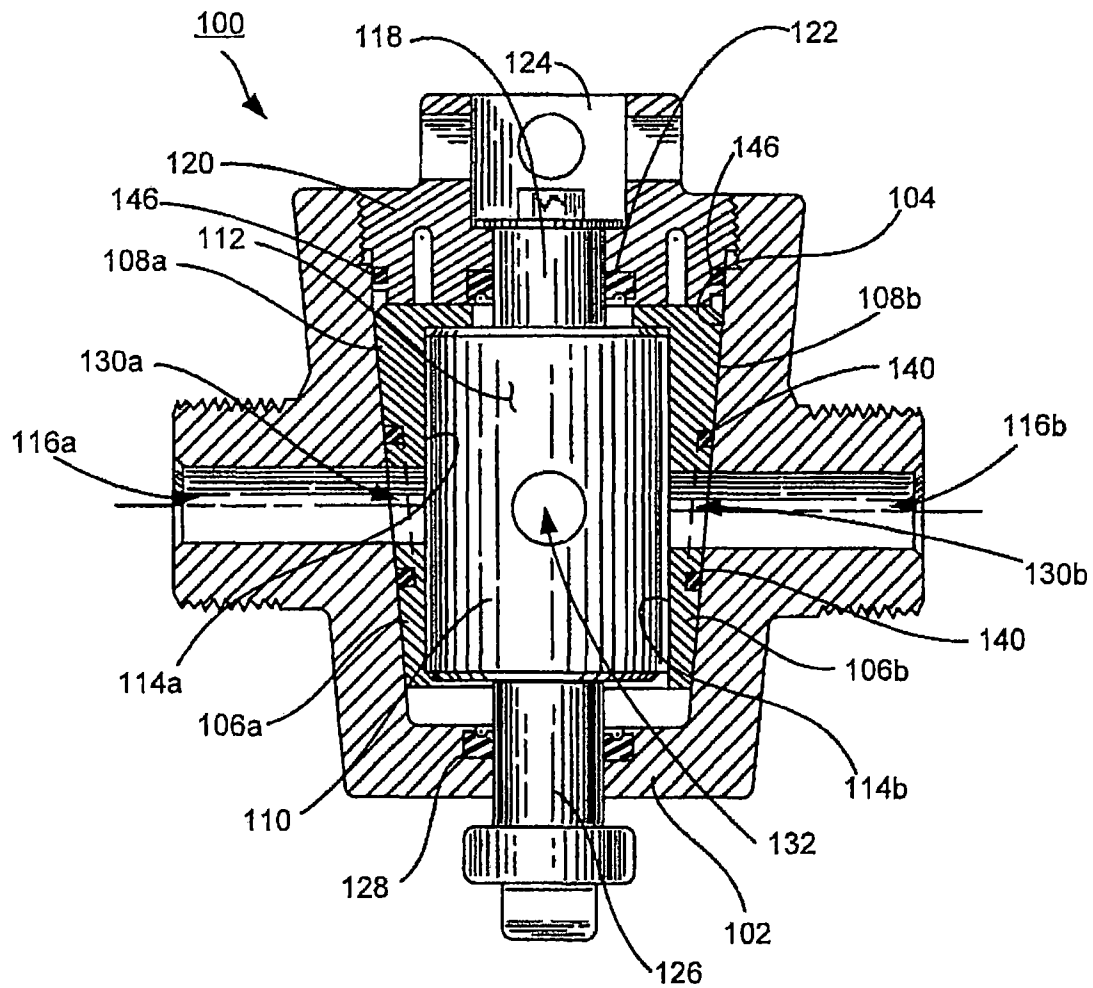


FIG. 1

PRIOR ART

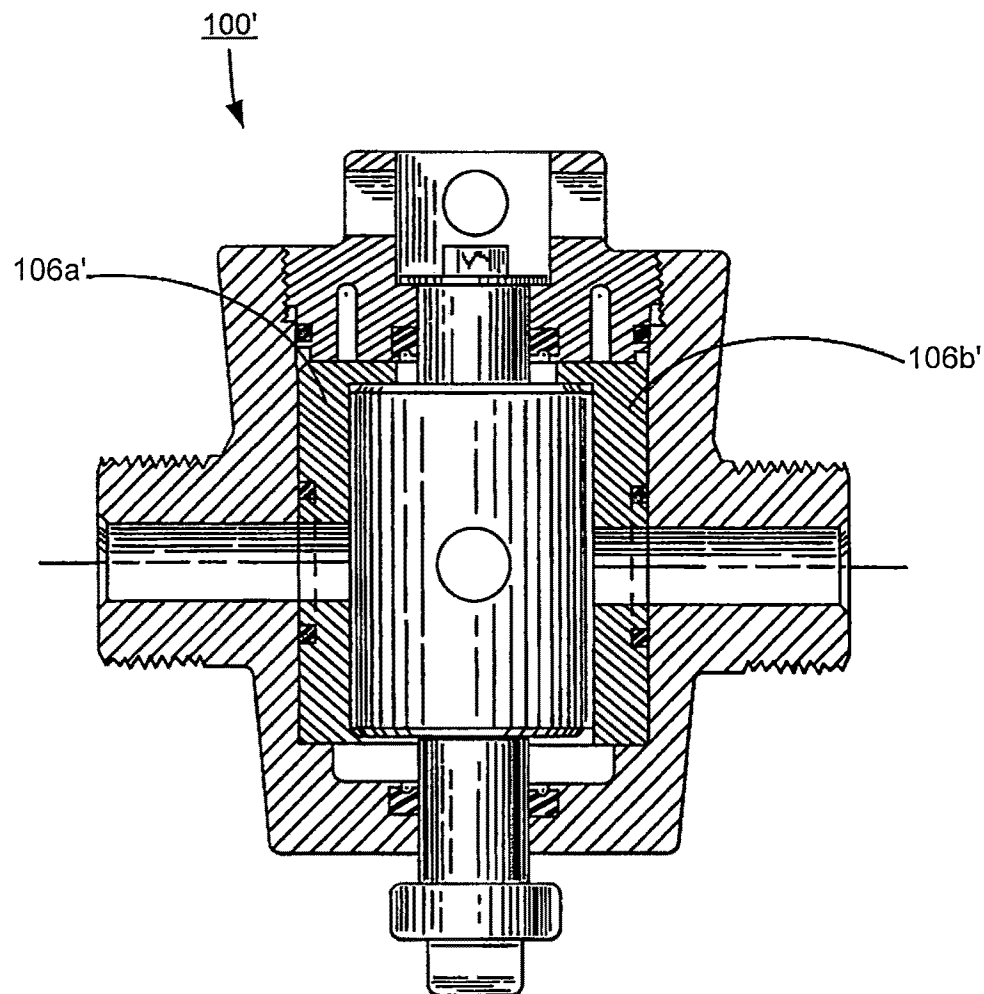


FIG. 2

PRIOR ART

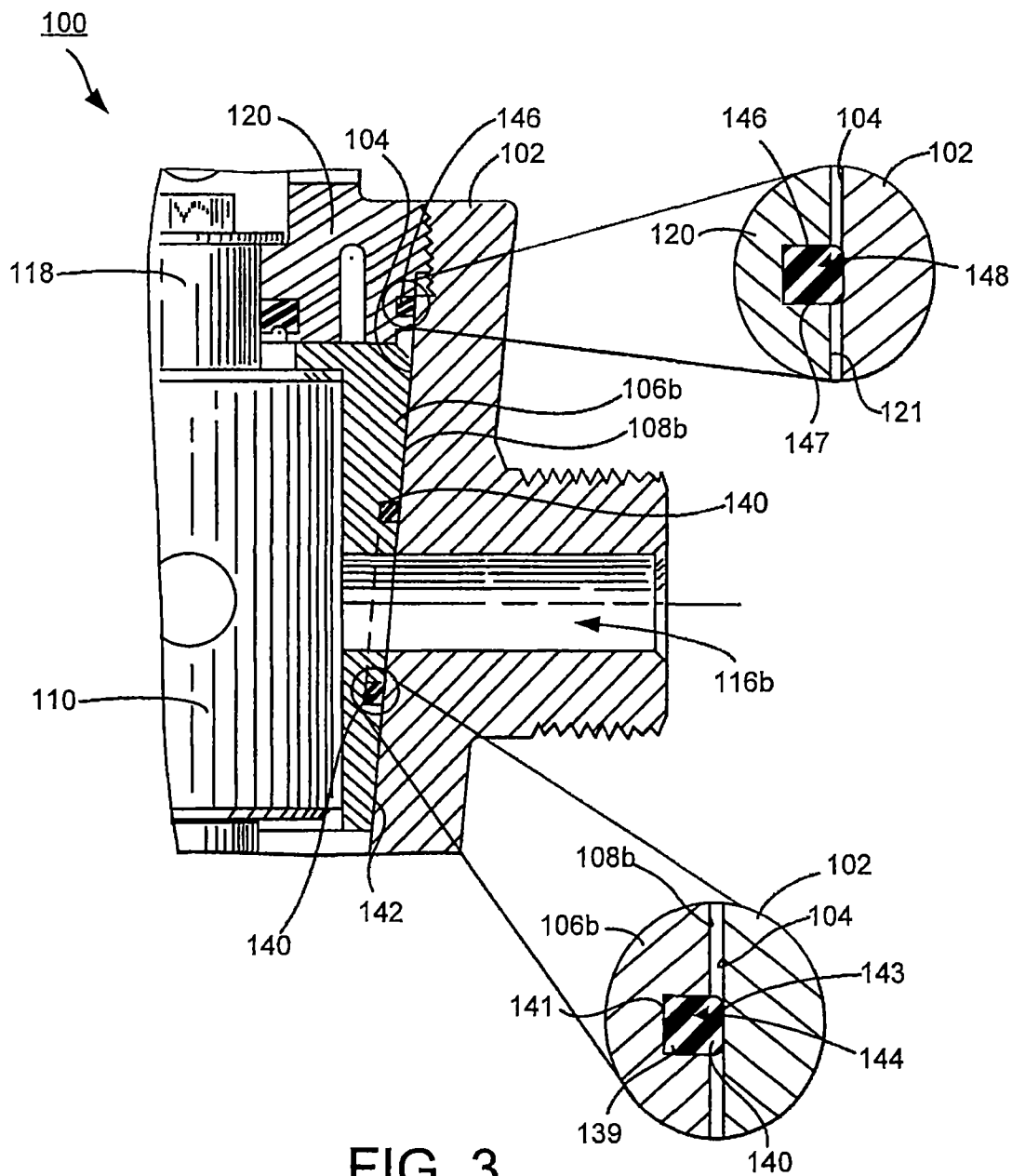


FIG. 3

PRIOR ART

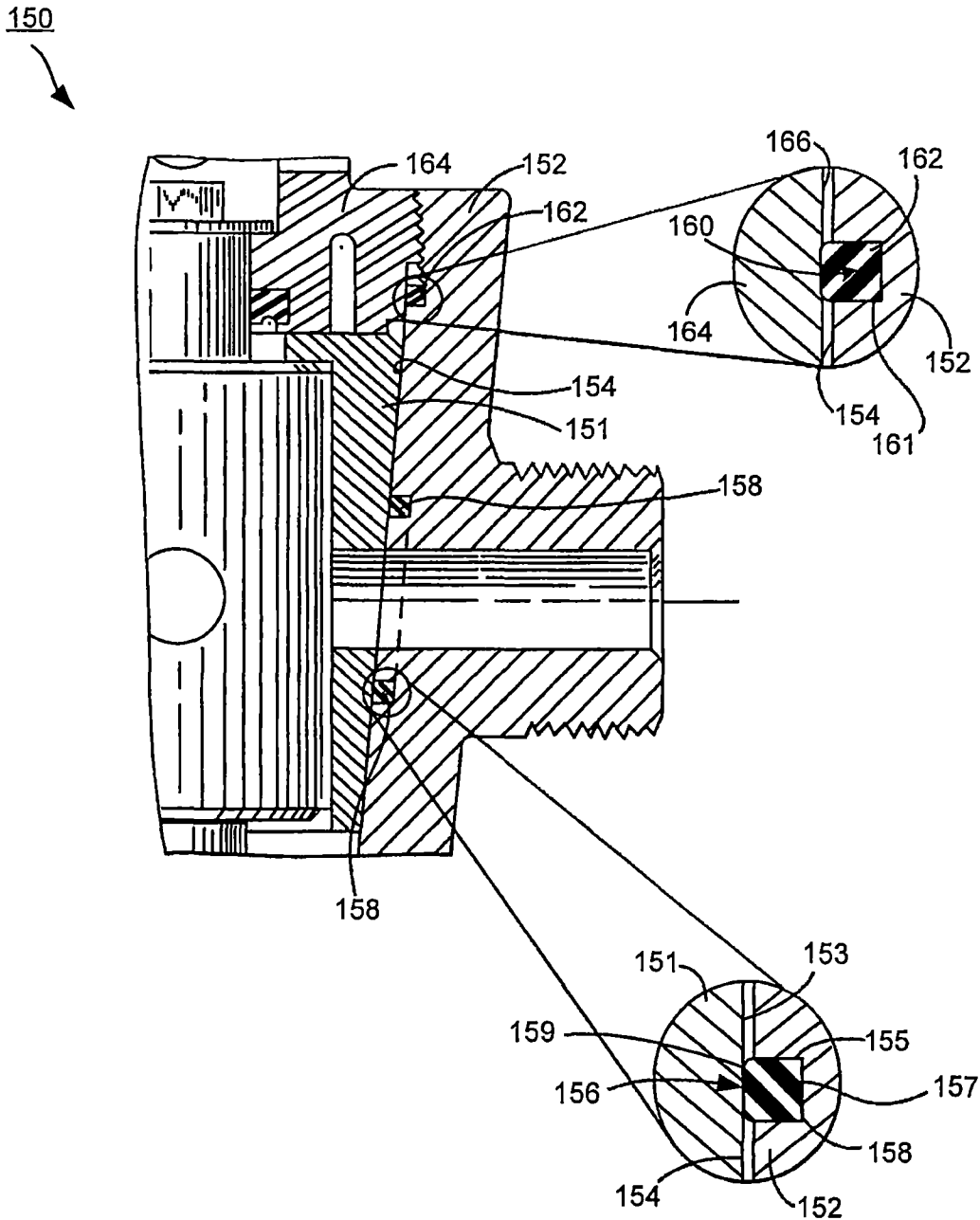


FIG. 4

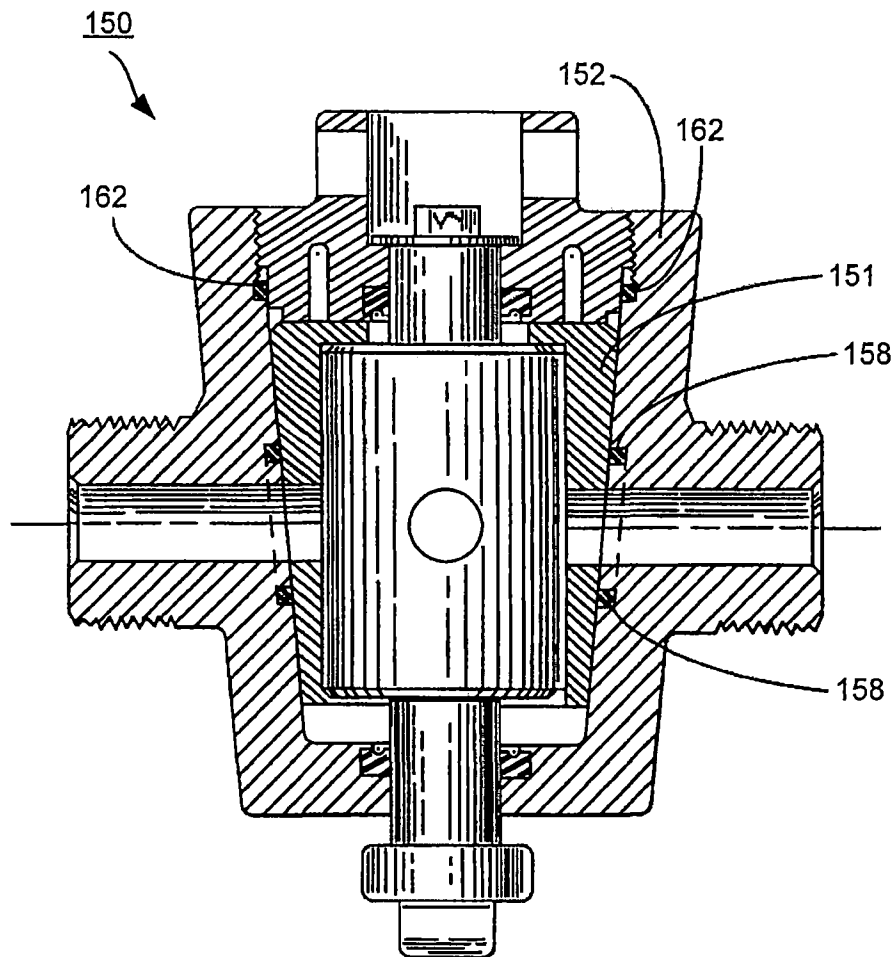


FIG. 5

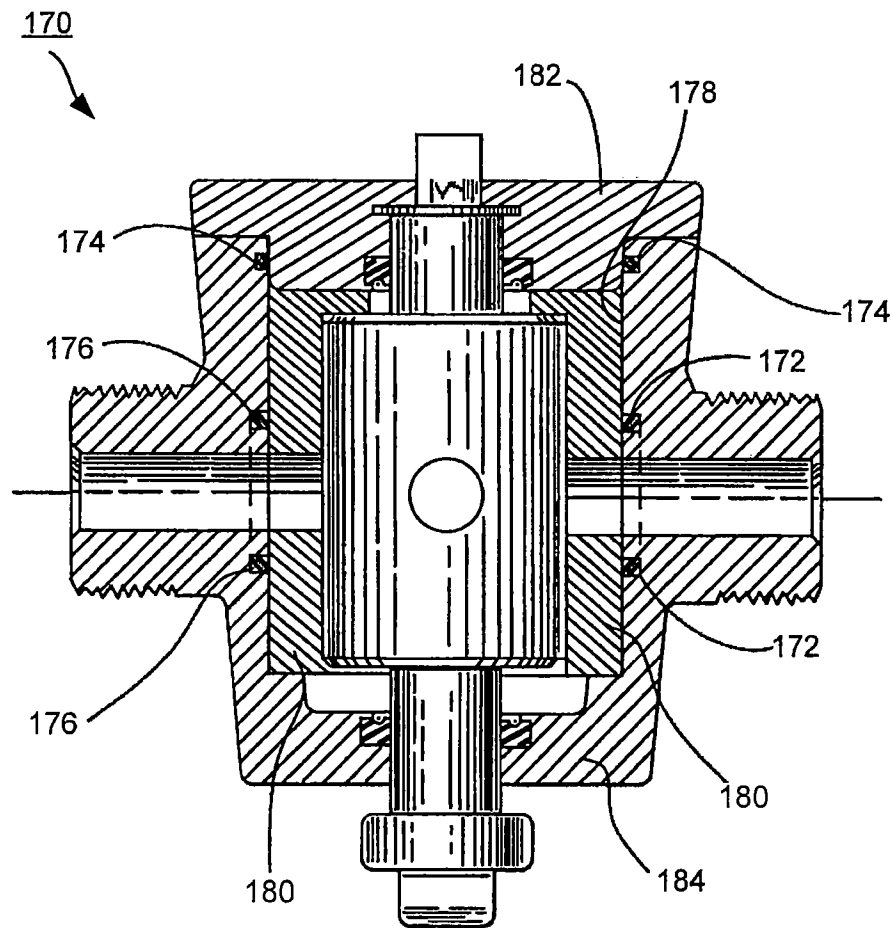


FIG. 6

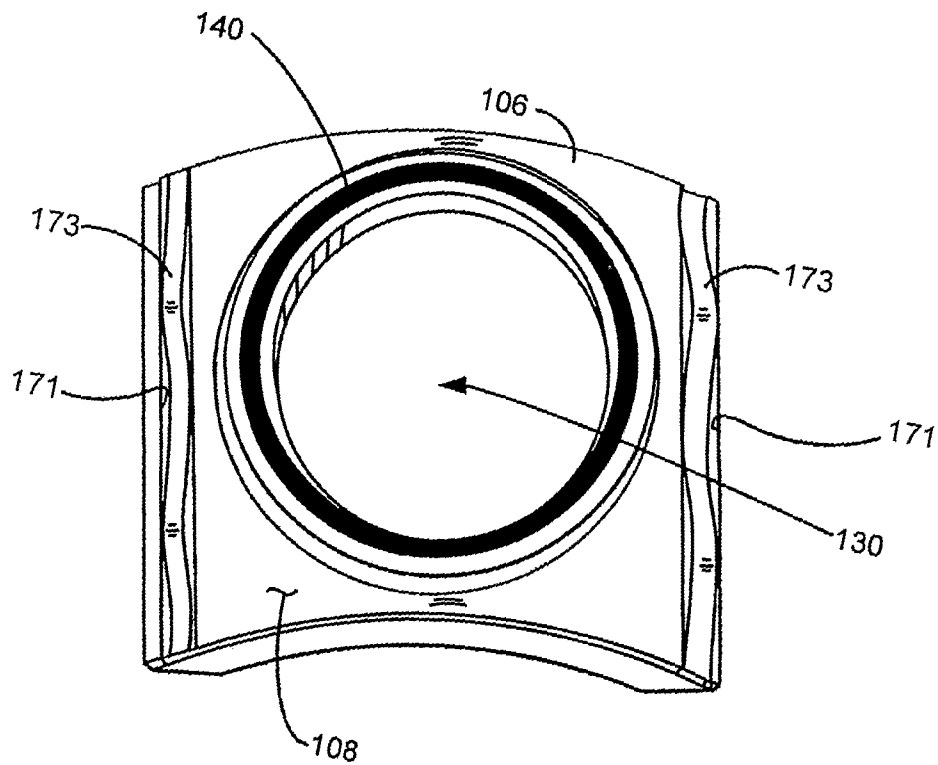
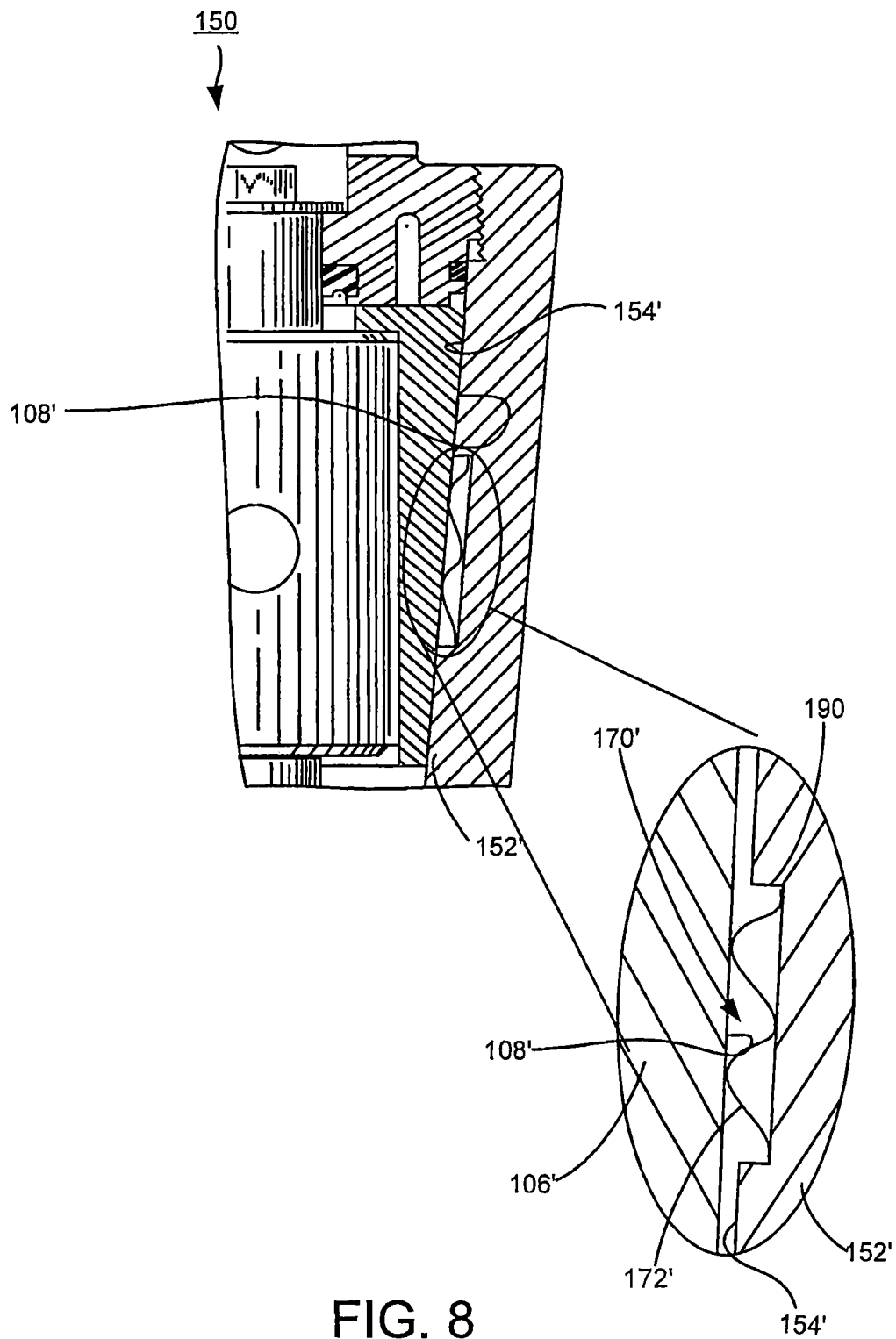
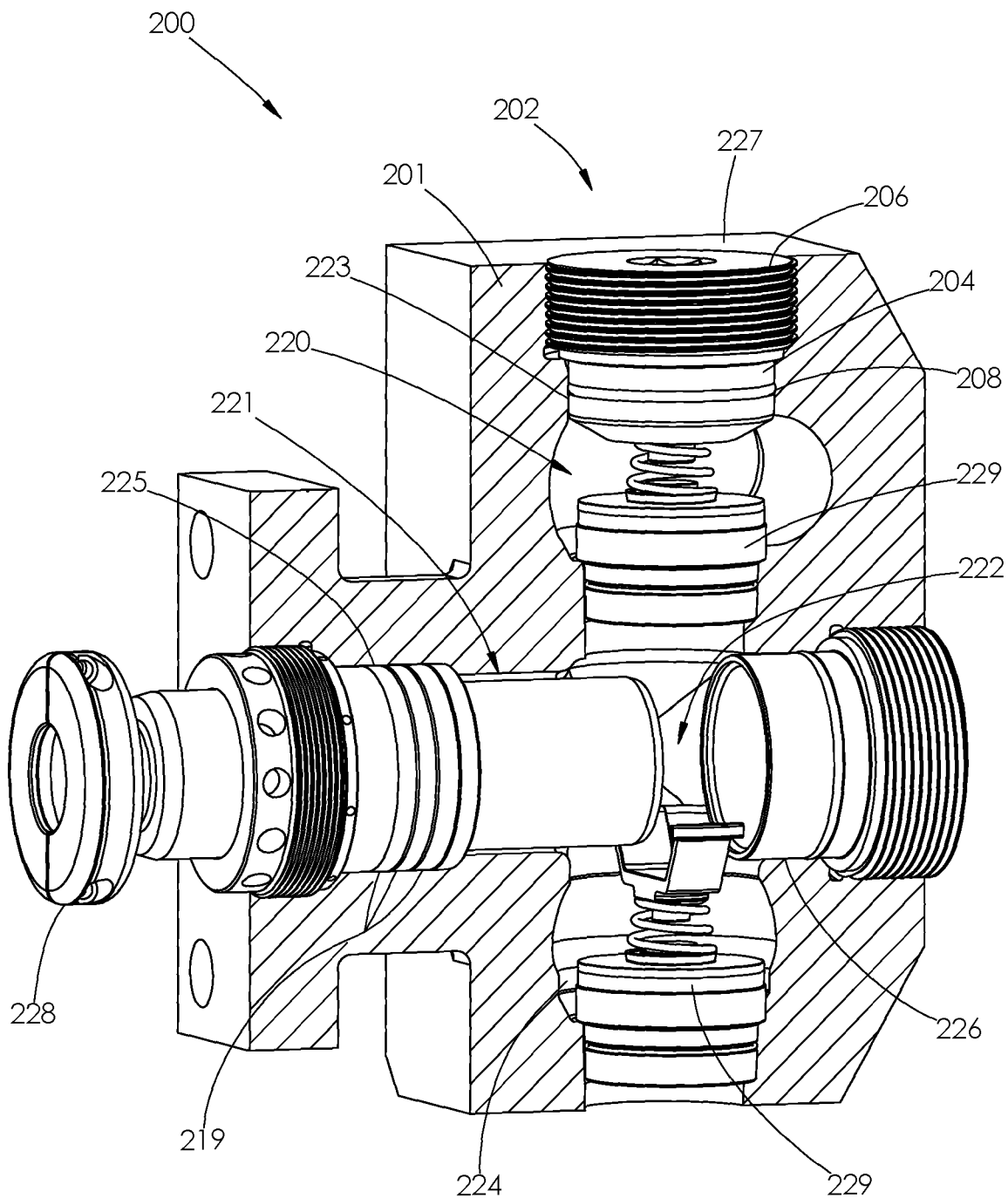


FIG. 7

PRIOR ART





PRIOR ART
FIG. 9

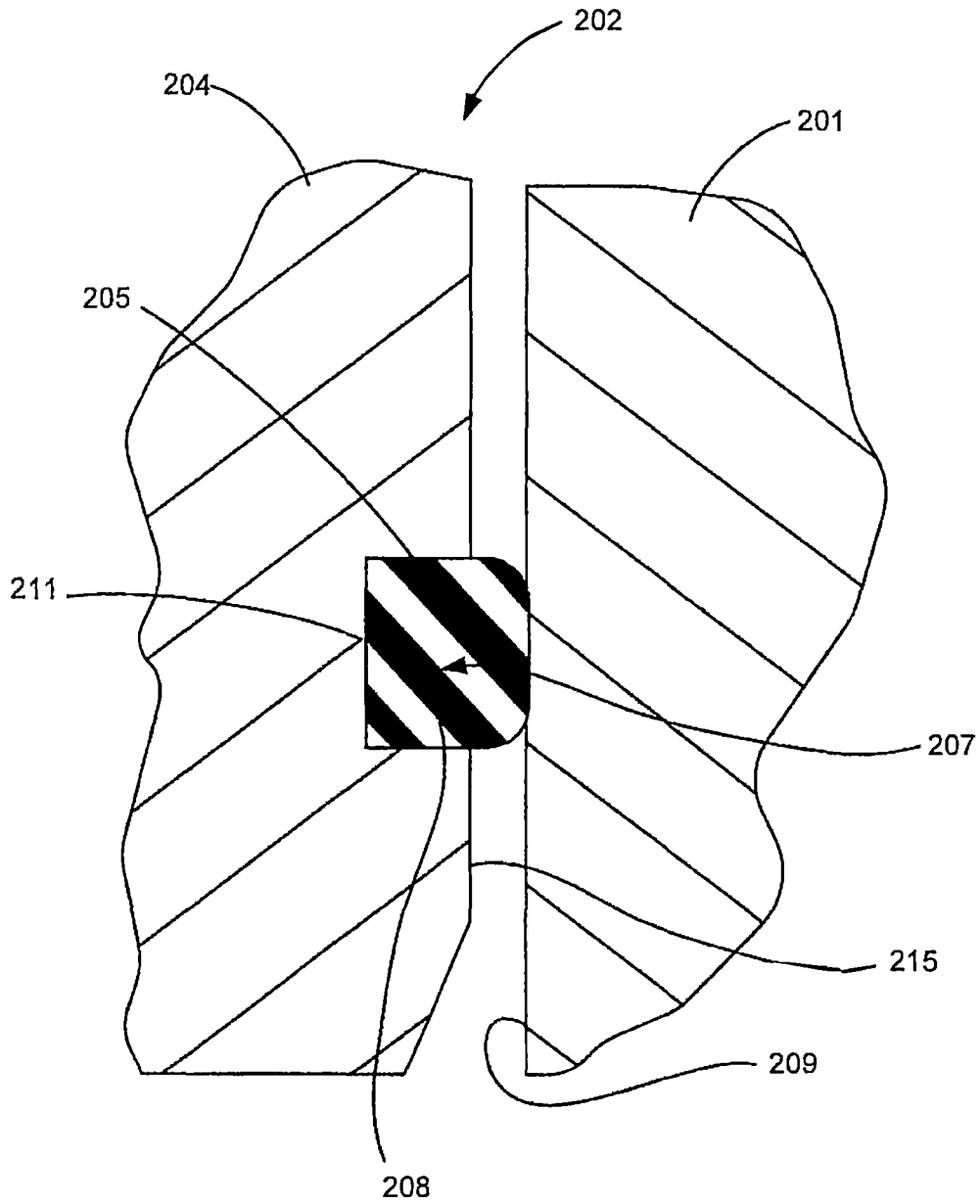
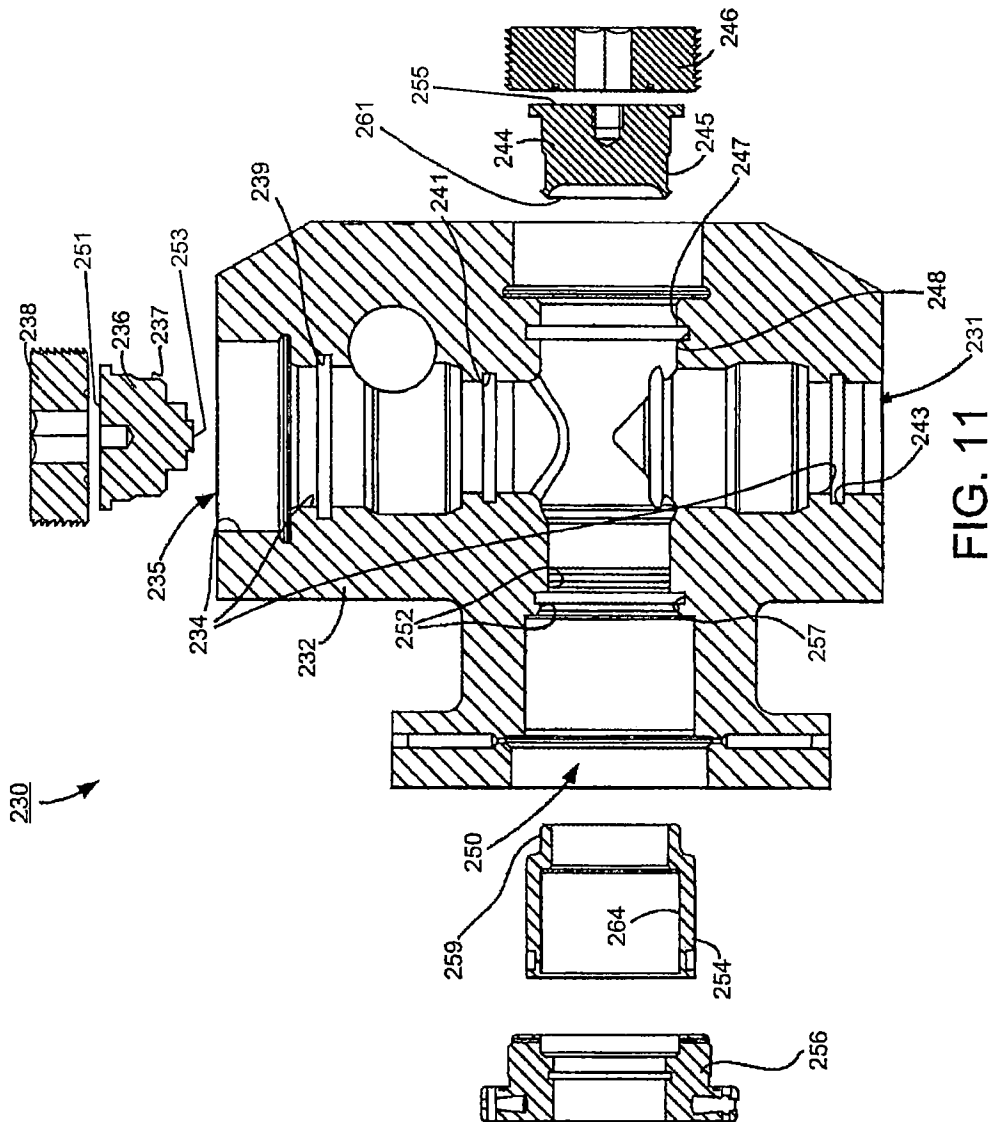


FIG. 10

PRIOR ART



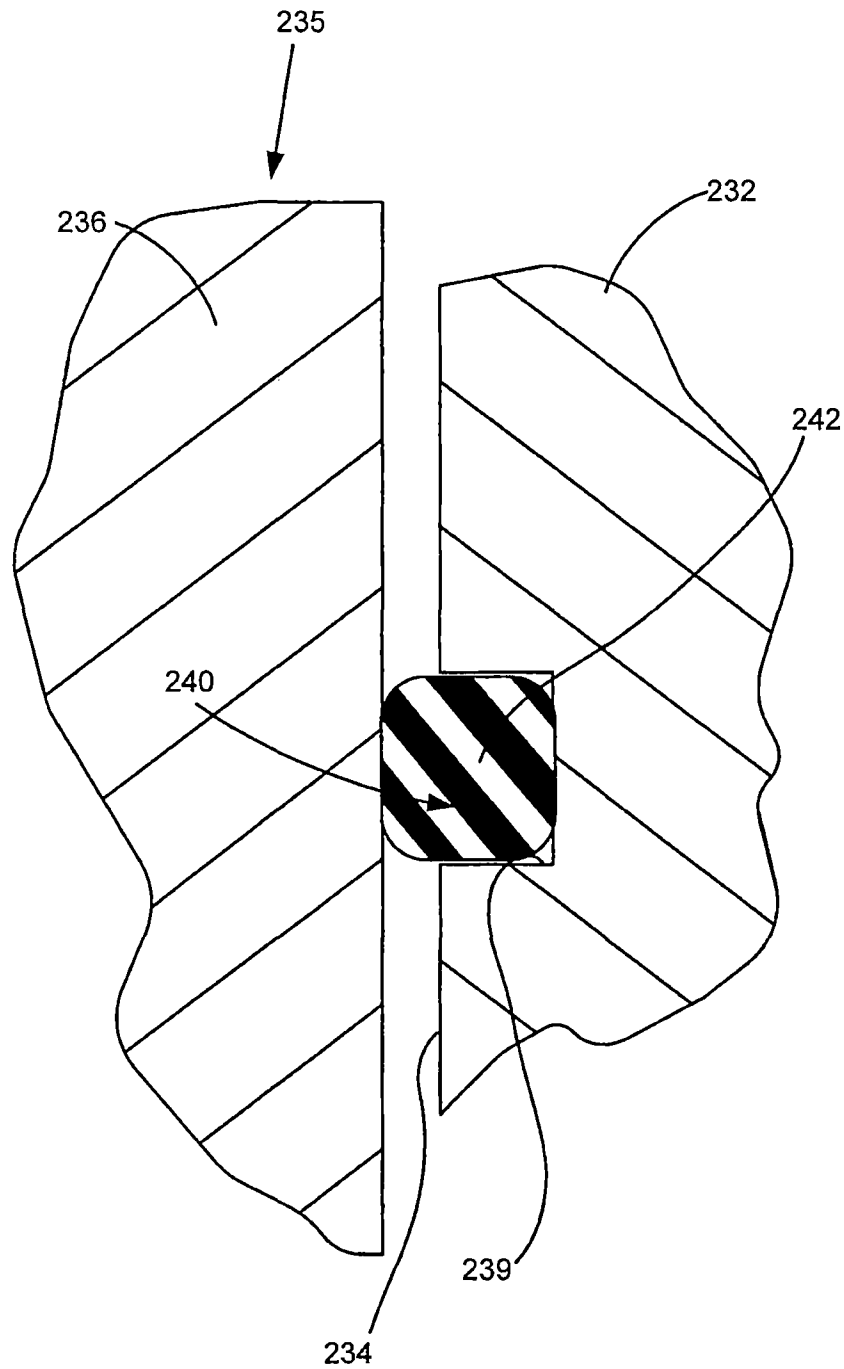


FIG. 12

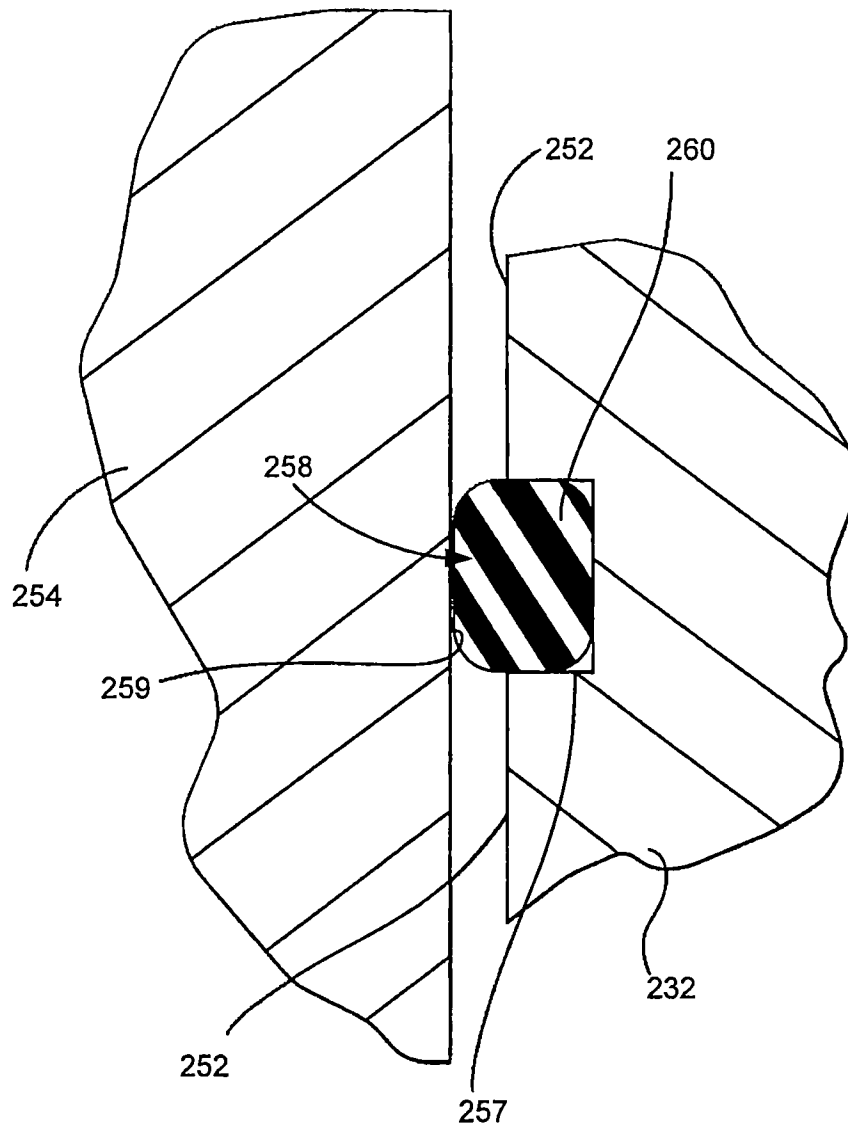


FIG. 13

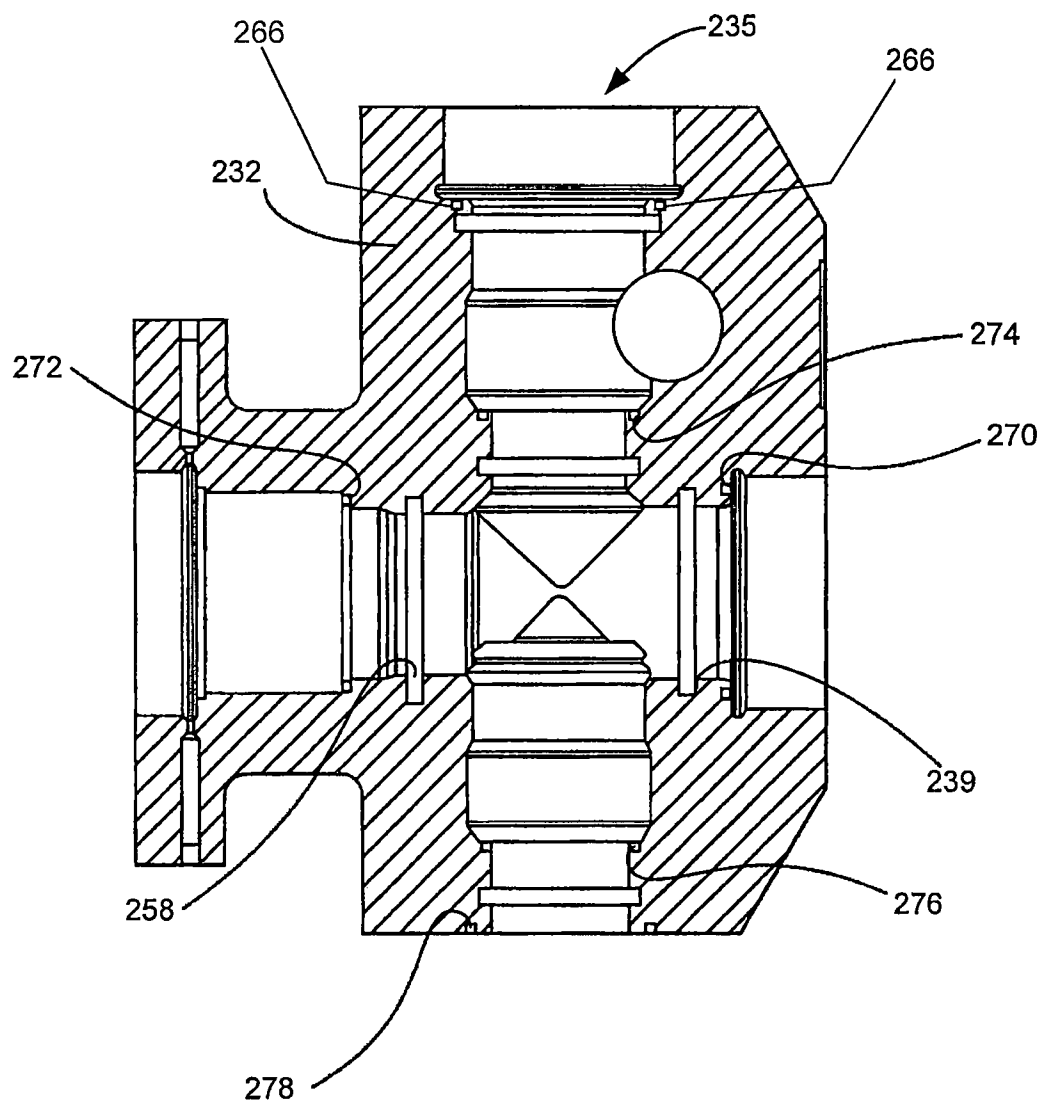


FIG. 14

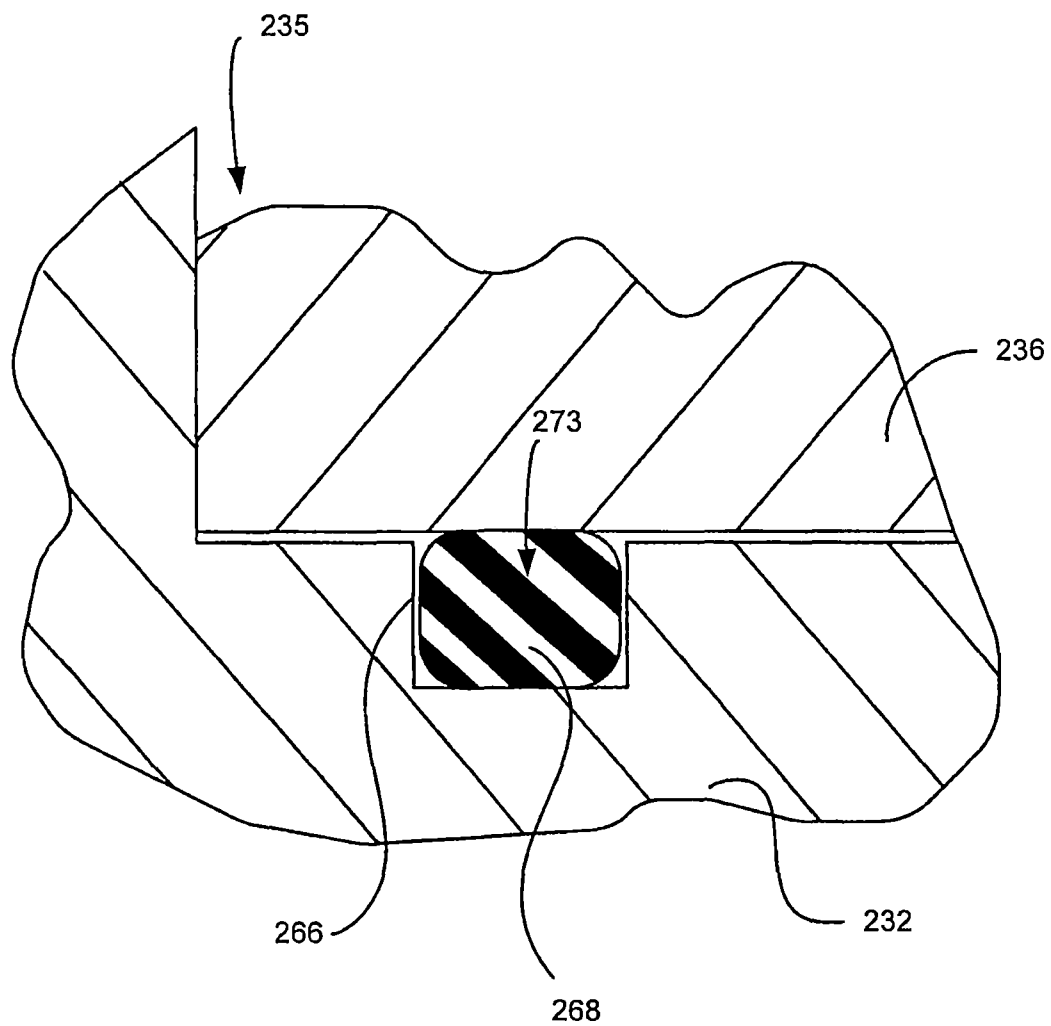


FIG. 15

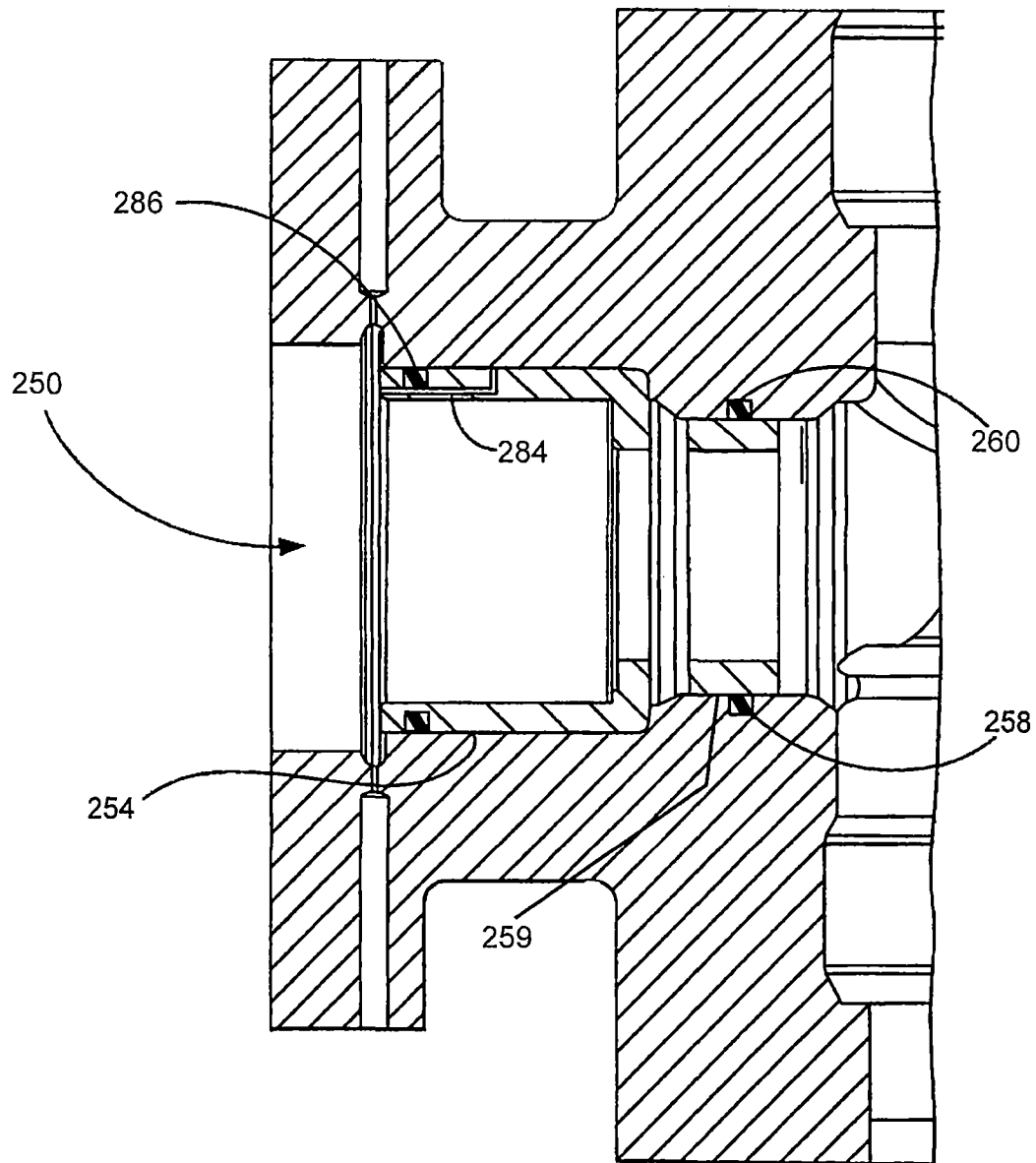


FIG. 16

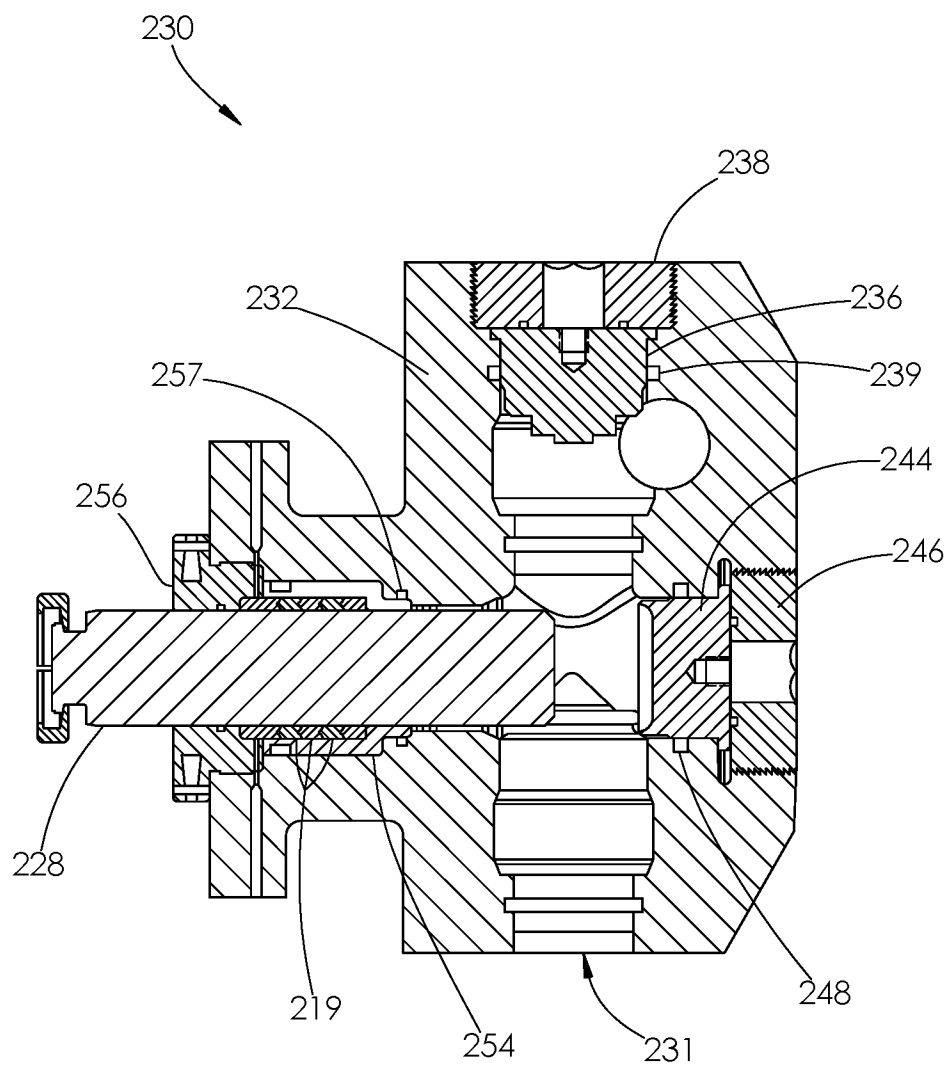


FIG. 17

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SEALING HIGH PRESSURE FLOW DEVICES**BACKGROUND**

This technology relates generally to sealing fluid flow passages inside flow control devices, such as those particularly suited for use in high pressure oil and gas production and processing systems.

One such type of flow control device is a valve. Generally, a valve forms a flow passage and has a selectively operable closure to open or close the flow passage in order to control a flow of fluid through the valve. The sealing integrity of high pressure valves must withstand not only high operating fluid pressures, presently 15,000 pounds per square inch and higher, but also must do so while controlling the flow of corrosive and/or abrasive fluids that are notorious for eroding the valve internal components in the oil and gas industry. Preferably, the valves can withstand pressures up to at least 22,500 pounds per square inch.

Illustrative embodiments herein are directed to a plug valve although the contemplated embodiments are not so limited. In a plug valve the flow passage typically includes a valve body in fluid communication with two or more openings, typically an inlet opening and an outlet opening, forming a flow passage through the valve body. A valve plug and insert segments, one type of a valve closure that is described herein, are disposed in a valve body bore between the inlet and outlet openings where sealing occurs between the plug, the insert, and the bore. The valve plug defines a through-opening and is selectively rotatable to an open position where the through-opening is aligned with the flow passage to permit a flow of fluid through the valve (from the inlet to the outlet), or to a closed position where the through-opening is misaligned with the flow passage to prevent the flow of fluid through the valve. Operating a valve in the harsh oilfield conditions can cause erosion of the valve body bore where the seal in the insert abrades against the bore, often resulting in leakage in a short amount of time. Repairing the valve body, such as by a weld build-up and machining operation, is a cumbersome and disruptive repair in the oilfield.

The illustrative embodiments of this technology directed to plug valves are in no way limiting of the contemplated embodiments of this technology. The skilled artisan understands that in alternative embodiments this technology can be used in other types of valves having differently configured closures. However, an enumeration of all the different types of valves that are suited for using this technology is not necessary for the skilled artisan to understand the scope of the claimed subject matter, so no such enumeration is warranted.

Besides valves, other types of high-pressure flow devices are also suited for practicing this technology. For example, a fluid end is used in many well servicing applications to contain high pressure, often corrosive and/or abrasive, fracturing fluids in the oil and gas industry. A fluid end typically has a manifold body and a number of components mounted and sealed to the body, such as the suction and discharge plugs, suction and discharge valve seats, stuffing box, discharge flange, and suction manifold; with those components either alone or sleeved as are illustratively described herein. Like the valves, operating a fluid end in the harsh oilfield conditions can cause erosion of the body resulting in leakage in a short amount of time. Repairing the body is also cumbersome and disruptive in the oilfield.

Improvements are needed in the internal sealing of high pressure flow devices to increase operating life while reduc-

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ing downtime and operating cost. What is needed is a solution that transfers the erosion (corrosion and abrasion) from the high pressure fluid device body to the component sealed with the body. It is to those improvements that embodiments of this technology are directed as described in the illustrative embodiments and contemplated within the scope of the claims.

SUMMARY OF THE INVENTION

The present invention is directed to a fluid end assembly comprising a housing having an external surface and an internal chamber, and a first conduit formed in the housing and having first and second sections, each section independently interconnecting the internal chamber and the external surface. The fluid end assembly further comprises a second conduit formed in the housing, intersecting the first conduit and independently interconnecting the internal chamber and the external surface, and an endless groove formed in the wall or walls defining one of the conduits and extending concentrically around that conduit.

The present invention is also directed to a fluid end assembly comprising a housing having an internal chamber and a conduit that intersects the internal chamber and opens at a first surface of the housing, a plunger that reciprocates within the housing, and a seal positioned within an annular groove formed in the housing.

The present invention is further directed to a method for manufacturing a fluid end assembly. The method comprises the steps of providing a housing having an external surface, an internal chamber, a first conduit formed in the housing having first and second sections, and a second conduit formed in the housing, intersecting the first conduit and having third and fourth sections independently interconnecting the internal chamber and the external surface, and forming an endless groove in the walls or walls defining one of the sections such that the groove extends concentrically around that section.

The present invention is also directed to a fluid end assembly having a housing having an external surface and an internal chamber, a first conduit formed in the housing and having first and second sections, and a second conduit formed in the housing, intersecting the first conduit. The fluid end assembly further comprises a recessed corner section formed in the wall or walls defining one of the conduits and extending concentrically around that conduit. The corner element is sized to receive a sealing element therein. The fluid end assembly further comprises a stuffing box installed in the same conduit within which the corner section is formed and having a tubular side wall that fully overlies that corner section. Each conduit independently interconnects the internal chamber and the external surface.

BRIEF DESCRIPTION OF THE DRAWINGS

Details of various embodiments of the present technology are described in connection with the accompanying drawings that bear similar reference numerals.

FIG. 1 is a cross-sectional depiction of a plug valve that is constructed in accordance with previously attempted solutions.

FIG. 2 is a cross-sectional depiction of another plug valve that is constructed in accordance with other previously attempted solutions.

FIG. 3 depicts enlarged portions of the plug valve in FIG. 1.

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FIG. 4 depicts enlarged portions similar to FIG. 3 but of a plug valve that is constructed in accordance with embodiments of this technology.

FIG. 5 depicts more of the plug valve of FIG. 4.

FIG. 6 is a cross-sectional depiction of another plug valve that is constructed in accordance with this technology.

FIG. 7 is an isometric depiction of a valve insert in the plug valve depicted in FIG. 1.

FIG. 8 is similar to FIG. 7 but depicting a different cross-section through the plug valve.

FIG. 9 is an isometric depiction of a fluid end that is constructed in accordance with embodiments of this technology.

FIG. 10 is an enlarged depiction of a portion of the fluid end of FIG. 9.

FIG. 11 is an exploded cross-sectional depiction of a fluid end that is constructed in accordance with embodiments of this technology.

FIGS. 12 and 13 are enlarged depictions of portions of the fluid end of FIG. 11.

FIG. 14 is a cross-sectional depiction of another fluid end that is constructed in accordance with embodiments of this technology.

FIGS. 15 and 16 are enlarged depictions of portions of the fluid end of FIG. 14.

FIG. 17 is the cross-sectional view of FIG. 11 with the components shown installed within the fluid end. A plunger and a plurality of packing seals are also shown installed within the fluid end.

DETAILED DESCRIPTION

Initially, this disclosure is by way of example only, not by limitation. The illustrative constructions and associated methods disclosed herein are not limited to use or application for sealing any specific assembly or in any specific environment. That is, the disclosed technology is not limited to use in sealing valves and fluid ends as described in the illustrative embodiments. Thus, although the instrumentalities described herein are for the convenience of explanation, shown and described with respect to exemplary embodiments, the skilled artisan understands that the principles herein may be applied equally in sealing other types of high pressure flow devices.

FIG. 1 is a cross-sectional depiction of a plug valve 100 that is constructed according to previously attempted solutions. The plug valve 100 has a forged valve body 102 forming a tapered internal bore 104. Inserts 106a, 106b in these illustrative embodiments are segments of an open hollow cone. Although two inserts 106a, 106b are depicted, the contemplated embodiments are not so limited because alternatively there can be more than two. Each insert 106a, 106b has an outer conical surface 108a, 108b forming a matching taper to engage against the bore 104 in a close mating relationship.

A cylindrical plug 110 has an outer diameter surface 112 sized to fill the space between the inserts 106, mating with an inner diameter surface 114a, 114b of the respective inserts 106. The plug 110 has a top journal 118 that is rotatable within a retaining nut 120. A packing 122 seals against the journal 118 to contain the pressurized fluid inside the valve 100 while permitting an external force to rotate the journal 118 and, in turn, the plug 110. In these illustrative embodiments a handle 124 is connected to the journal 118 to permit a user to manually rotate the plug 110. In alternative embodiments not depicted the journal 118 can be rotated by

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a powered actuator. The plug 110 also has a bottom journal 126 that rotates within the body 102 and is sealed by packing 128.

The body 102 also forms openings 116a, 116b intersecting the bore 104, typically referred to as an inlet and an outlet. For illustrative purposes of this description it is a given that the fluid flows through the valve 100 from left to right, or into the opening 116a and out of the opening 116b. However, in practice either opening 116 can provide the inlet and the other opening 116 the outlet.

Each insert 106 forms a respective opening 130a, 130b, and the inserts 106 are mounted in the valve 100 so that the insert openings 130 are aligned with the respective valve body opening 116. The plug 110 forms a through-opening 132 permitting a user to selectively align the opening 132 with the openings 116. FIG. 1 depicts the closed position of the valve 100, where the plug 110 is rotated so that the through-opening 132 is misaligned with the openings 116.

Namely, in the closed position of the valve 100 depicted in FIG. 1, pressurized fluid connected to the opening 116a (inlet) impacts against the closed plug 110, sealing the backside of the plug in a metal-to-metal seal against the insert 106b and also sealing between a seal 140 mounted in the insert 106b between it and the valve body bore 104. Thus, in the closed position the pressurized fluid is blocked from flowing through the valve 100. By rotating the plug 110 to the open position (not depicted), its through-opening 132 comes into alignment with the openings 116, permitting the pressurized fluid to flow through the valve 100 via a flow passage established collectively by the valve body openings 116, the insert openings 130, and the valve plug through-opening 132.

FIG. 2 is similar to FIG. 1 but depicting a top entry plug valve 100' that is constructed in accordance with other previously attempted solutions. The plug valve 100' has inserts 106a', 106b' that are formed as segments of an open hollow cylinder instead of the inserts 106a, 106b in FIG. 1 that are segments of an open hollow cone. In other words, the conical surfaces in FIG. 1 are replaced here with cylindrical surfaces. Due to this, the inner body of the plug valve 100' is not tapered, unlike the plug valve 100. For purposes of this description the skilled artisan understands that the details of construction and use of this technology applies equivalently to both types of these valves, as well as other types of valves that are used to control highly pressurized fluid. Thus, the skilled artisan understands the scope of the claims from this description's comparison to the details of construction for just one of the previously attempted solutions.

Continuing with the previously started description in comparison to the previously attempted solutions depicted in FIG. 1, FIG. 3 is an enlarged portion of it more particularly depicting how the high pressure fluid is contained inside the valve 100 in part by the seal 140 that is compressed between the outer conical surface 108b of the insert 106b and the valve body bore 104.

The insert 106b has a surface 139 defining a recess 144 intersecting the outer conical surface 108b. The term "intersecting" for purposes of this description and meaning of the claims means that the recess 144 forms a gap in the outer surface 108b of the insert 106b. That intersecting construction of the recess 144 with the surface 108b permits mounting a fixed end 141 of the seal 140 in the recess 144, and sizing the seal 140 so that a distal end 143 extends from the recess 144 beyond the outer conical surface 108b in order to seal against the valve body bore 104. Importantly, this requires the bore 104 to define a sealing surface 142 against

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which the seal **140** in the insert **106b** presses against to effect the sealed engagement of the insert **106b** against the bore **104**. Corrosive and/or abrasive fluid can become trapped between the seal **140** (mounted in the insert **106b**) and the bore **104** causing erosion of the bore **104**. The seal **140** in these embodiments is referred to as an axial seal because the compressive forces from the surface **108b** on one side and the bore **104** on the other side act in an axial direction relative to the annular seal **140**.

Although the embodiments of FIG. 3 depict only one annular seal **140** surrounding the outlet **116b**, the previously attempted solutions are not so limited. The skilled artisan understands that in alternative constructions more than one seal can be used to provide redundancy. The seal **140** can be an elastomeric seal, and in other embodiments other kinds of seals can be used such as metal seals, spring seals, and the like.

To enclose the valve plug **110** and support the journal **118**, a retaining nut **120** is threaded to the valve body **102**. The retaining nut **120** seals to the valve body bore **104** by another seal **146**. Similar to the insert **106b**, the retaining nut **120** has a surface **147** defining a recess (sometimes referred to as a “gland”) **148** intersecting an outer diameter surface **121** of the retaining nut **120**. The seal **146** is supported in the recess **148** and is sized to extend beyond the outer surface **121** to seal against a sealing surface formed by the valve body bore **104**. The seal **146** in these embodiments is referred to as a radial seal because the compressive forces from the cap’s surface **121** on one side and the bore **104** on the other side act in a radial direction relative to the annular seal **146**. Although a radial seal is depicted, in alternative embodiments an axial seal or a crush seal and the like can be used instead of or in addition to the radial seal.

In comparison, FIG. 4 is similar to FIG. 3 but depicts a portion of a valve **150** that is constructed in accordance with embodiments of this technology. Here an insert **151** is similar in some respects but does not have a seal mounted to it like the insert **106b** (FIG. 3). Particularly, the insert **151** has an outer conical segment surface **153** that does not form a recess for mounting a seal. There is no gap in the surface **153** where a recess intersects for mounting a seal. Instead, a valve body **152** defines a valve body bore **154**, and also has a surface **155** defining a recess **156** intersecting the bore **154**. Again, the term “intersecting” for purposes of this description and meaning of the claims means that the recess **156** includes a gap in the bore **154**. Particularly, a fixed end **157** of a seal **158** is mounted in the recess **156**, and because the recess **156** intersects the bore **154**, the seal **158** can be sized to extend from the recess **156** beyond the bore **154** so that a distal end **159** of the seal **158** seals against a sealing surface formed by the insert **151**.

Corrosive and/or abrasive fluid can become trapped between the seal **158** (mounted to the body **152**) and the insert **151** causing erosion of the outer cylindrical surface of the insert **151**. Importantly, in comparison to the previously attempted solutions, the construction of FIG. 4 advantageously transfers the erosion wear from the bore **154** (of the body **152**) to the insert **151**. When erosion has progressed to the extent that leakage occurs, repairing or replacing the insert **151** is significantly less complex and less expensive than repairing the body **152**.

The body **152** also has a surface **161** forming another recess **160** that intersects the valve body bore **154**. A seal **162** is mounted to the body **152** in the recess **160**. Again, because of the intersecting construction of the recess **160** and the bore **154**, the seal **162** can be sized to extend beyond the bore **154** to seal against a sealing surface formed by a retaining

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nut **164**. Unlike the retaining nut **120** in FIG. 3, retaining nut **164** does not have a seal mounted to it. Instead, the seal **162** is mounted to the valve body **152** and is sized to extend from the recess **160** to seal against the outer diameter surface **166** of the retaining nut **164**. In the same way as described above, this technology transfers the erosion wear away from the body **152** to the less complex and less expensive mating component, in this case the retaining nut **164**.

FIG. 5 is a simplified depiction of the valve **150** that is constructed in accordance with the present technology. The skilled artisan understands that variations in construction are encompassed within the contemplated embodiments of this technology that are represented in the illustrative embodiments. For example, FIG. 6 depicts another valve **170** that is constructed in accordance with this technology because each of the seals **172**, **174**, **176** are mounted in respective recesses formed in the valve body **184** and intersecting the valve body bore **178**. The seals **172**, **174**, **176** are configured to extend away from the respective recesses to seal against sealing surfaces of the inserts **180** and the retaining nut **182**, correspondingly. Unlike the previously attempted solutions, this construction eliminates the erosion caused by mounting a seal to a mating component that seals against the valve body bore **178**.

FIG. 7 is an isometric depiction of the insert **106** in the previous valve design depicted in FIG. 1. In these embodiments the insert **106** defines slots **171** intersecting the outer conical surface **108** of the insert **106**. A spring **173** is mounted to the insert **106** in each slot **171** and extends from the slot **171** to contact the valve body bore **104** (FIG. 1). As described above, that construction of the previously attempted solutions, by design, makes the valve body bore **104** the sacrificial member for any erosion caused by the springs **173**.

FIG. 8 depicts a portion of the valve **150** (of this technology) in FIG. 5, but at a different cross section that passes through a recess **170'** defined by a surface **190** formed by the valve body **152'**. The recess **170'** intersects the valve body bore **154'** so that a spring **172'** can be mounted in the recess **170'** at a fixed end and sized to extend from the recess **170'** to pressingly engage against an outer conical surface **108'** of the insert **106'**. Like described above, this technology transfers the wear from the valve body bore **154'** to the less complex and less expensive insert **106'**.

Returning momentarily to FIG. 5 that depicts the plug valve **150** constructed in accordance with embodiments of this technology. The skilled artisan having read this description understands that this technology transfers the erosion wear from the bore of the body **152** to the outer conical surface of the insert **151**. As described, leakage can occur because the free end of the seal **158** abrades away the outer conical surface of the insert **151**. In some illustrative embodiments the repair procedure can entail resurfacing the insert **151** to provide a new sealing surface for the seal **158** mounted in the body **152**. Alternatively, the insert **151** can simply be replaced with a new one.

In yet other alternative embodiments a disposable wear member can be provided between the outer conical surface of the insert **151** and the bore of the body **152**. For purposes of this description and the claims the disposable wear member can be a disposable liner (not depicted) with one surface facing the bore of the body **152** to function effectively the same as the outer conical surface of the insert **151**. In some embodiments an opposing inner surface of the liner can mate directly to the outer conical surface of the insert **151**. Alternatively, a seal can be provided between the inner surface of the liner and the outer conical surface of the insert.

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That seal can be mounted to the insert and extending to seal against a sealing surface formed by the liner (such as by using the insert **106** in FIG. **1**), or the seal can be mounted to the inner surface of the liner and extending to seal against a sealing surface formed by the outer surface of the insert.

Turning to another type of flow device that is well-suited for practicing this technology, FIG. **9** is a simplified isometric cross-sectional depiction of a hydraulic fracturing fluid end **200** that is constructed in accordance with previously attempted solutions. The fluid end **200** is generally a manifold **201** used to deliver highly-pressurized corrosive and/or abrasive fluids, typically used in hydraulic fracturing processes in the oil and gas industry. Fluid may pass through the fluid end **200** at pressures that range from 5,000-15,000 pounds per square inch (psi). Fluid ends **200** used in high pressure hydraulic fracturing operations typically move fluid at a minimum of 8,000 psi. However, normally, the fluid end **200** will move fluid at pressures around 10,000-15,000 psi.

The manifold body or housing **201** typically has a first conduit **220** and a second conduit **221** formed within the body **201** that intersect to form an internal chamber **222**. The first conduit **220** is typically orthogonal to the second conduit **221**. The first conduit **220** may have aligned first and second sections **223** and **224** that are situated on opposite sides of the internal chamber **222**. Likewise, the second conduit **221** may have aligned third and fourth sections **225** and **226** that are situated on opposite sides of the internal chamber **222**. The sections **223**, **224**, **225**, and **226** each may independently interconnect the internal chamber **222** to an external surface **227** of the fluid end **200**.

A plunger **228** reciprocates within the body **201** to increase the pressure of fluid being discharged from the fluid end **200**. As shown in FIG. **9**, the plunger **228** may be disposed within the third section **225** of the second conduit **221**. The plunger **228** is disposed within a plurality of packing seals **219**. The plunger **228** is powered by an engine operatively engaged with the fluid end **200**. In high pressure hydraulic fracturing operations, the engine preferably has a power output of at least 2,250 horsepower. Valve seats **229** are also shown within the first conduit **220**. The valve seats **229** may support valves, such as a ball valve, used to control the movement of high pressure fluid within the body **201**.

There are sealing areas in the fluid end **200** that experience the kind of erosion issues described above in plug valves. Similar to the conventional plug valve **100** depicted in FIG. **1**, a number of components seal to the manifold body **201**. Here, again, the sacrificial member for erosion, by design, is the body **201** instead of the less complex and less expensive mating component.

For example, the body **201** defines a discharge opening **202** that opens into the first conduit **220**. The discharge opening **202** depicted in these embodiments is sealed closed by inserting a closure or discharge plug or cover **204** into the conduit **220** and securing it by advancing a retaining nut **206** into the body **201**. The discharge plug **204** supports a seal **208** that seals against the bore defining the discharge opening **202**. FIG. **10** is a simplified cross-sectional depiction of the discharge plug **204** that has a surface **205** defining a recess **207** into which the seal **208** is mounted at an inner radial surface **211** of the radial seal **208**.

In these illustrative embodiments the recess **207** is rectangular but the contemplated embodiments are not so limited. The skilled artisan understands that the configuration of the recess **207** is largely determined by what shape is required to mount the type of seal selected. The recess **207** intersects an outer surface **215** of the discharge plug **204**, permitting the seal **208** to be sized so that a portion not

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mounted within the recess **207** extends beyond the outer surface **215** to pressingly engage against the bore **209** defining the discharge opening **202**. In this construction the highly-pressurized corrosive and/or abrasive fluid can harsh fluid can be injected between the seal **208** and the bore **209**, causing erosion of the seal surface formed by the bore **209**. This technology transfers that erosion wear from the body bore **209** to the less complex and less expensive discharge plug **204**.

Fluid end bodies have conventionally been made of heat-treated carbon steel, so it was not uncommon for the body **201** to crack before any sacrificial erosion of the body progressed to the point of creating leakage between the discharge plug **204** and the bore **209**. However, progress in the technology has introduced stainless steel body construction resulting in a significantly longer operating life. As a result, this erosion is no longer negligible but is instead a consideration for reducing erosion in modern fluid end construction. One leading source of bore **209** erosion in conventional fluid ends is the seal **208** mounted in the discharge plug **204** and extending therefrom to seal against a sealing surface formed by the body **201**.

FIG. **11** is an exploded cross-sectional depiction of a fluid end **230** that is constructed in accordance with this technology to, in numerous places, transfer the erosion wear from the body to the less complex and less expensive component that is sealed to the body. A manifold body **232** forms a number of interconnected bores or conduits, including a first conduit or discharge bore **234** forming a discharge opening **235** that is similar to the discharge opening **202** in the conventional fluid end **200** depicted in FIG. **9**. The discharge bore **234** further defines an intake opening **231** formed opposite the discharge opening **235**. The term "discharge bore" for purposes of this description means the surface defining the discharge opening **235** into which a closure or discharge plug **236** and a retaining nut **238** are installed, and the surface defining the intake opening **231**. For clarity, although FIG. **11** references the discharge bore **234** as defining an upper end of the discharge opening **235** where the retaining nut **238** attaches, the discharge bore **234** also references lower portions of the discharge opening **235** where the discharge plug **236** seals to the body **232** and where the valve seat (not depicted) seals to the body **232**. Likewise, the discharge bore **234** also references upper portions of the intake opening **231**. Generally, for purposes of this description the discharge bore **234** forms multi-dimensional diameters at different longitudinal locations of the discharge opening **235** and intake opening **231**.

The discharge opening **235** is sealed closed by inserting the discharge plug **236** into the discharge opening **235** and securing it in place by advancing the retaining nut **238**, as shown in FIG. **17**. Unlike the conventional plug **204** in FIG. **9**, however, the plug **236** does not have a seal mounted to it that seals against the bore **234**. Instead, the plug **236** defines a sealing surface **237** for a seal (not depicted in FIG. **11**) that is mounted in an endless groove or recess formed by a surface **239** of the body **232**. The sealing surface **237** is axially spaced between a first surface **251** and an opposite second surface **253** of the plug **236**.

FIG. **12** is a simplified cross-sectional enlargement depicting the construction of the seal positioned within the surface **239** of the body **232**. The surface **239** forms an endless groove or recess **240** that intersects the discharge bore **234**. A seal **242** in these illustrative embodiments is mounted in the recess **240** to include an outer radial surface, and is thereby supported by the body **232**. The recess **240** is characterized by a pair of parallel sidewalls joined by a base.

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The recess **240** opens towards a centerline of the conduit within which it is formed. Alternatively, as shown by recess **266** in FIGS. **14-15**, the recess may open in a direction parallel to a centerline of the conduit within which it is formed. As above, the rectangular-groove shape of the recess **240** is merely illustrative and not limiting of the contemplated embodiments. Any shape necessary to properly mount a desired seal is contemplated, whether the seal is elastomeric, spring, metal, and the like. As above, the recess **240** intersects the bore **234** permitting the seal **242** to be sized so that a portion of the seal **242** not contained in the recess **240** extends beyond the recess **240** and beyond the bore **234** to pressingly seal against the sealing surface **237** (FIG. **11**) defined by the discharge plug **236**.

This seal construction depicted in FIG. **12** transfers the erosion wear from the body to the discharge plug. That significantly improves fluid end operations because repairs involving the discharge plug **236** are significantly less complex and less expensive than repairs involving the body **232**, which typically involve weld-repair. Furthermore, weld-repairing the body **232** makes it susceptible to premature fatigue cracking in the repaired area. Further, even more operating life can be achieved by applying an erosion-resistant surface treatment to the plug **236**, such as a high velocity oxygen fuel (HVOF) treatment, a tungsten carbide coating, material carburizing, and the like. Replacing instead of repairing an eroded discharge plug **236** is typically feasible, making it advantageously possible to repair a leaking valve constructed according to this technology in the field and thereby significantly reducing down time.

Returning to FIG. **11**, the body **232** has a surface **241** defining an endless groove or recess intersecting the bore **234** and configured to mount a seal (not depicted) that extends from the recess to seal against a sealing surface formed by a discharge valve seat (not depicted). Similarly, the body **232** has a surface **243** forming another endless groove or recess intersecting the bore **234** and configured to mount another seal (not depicted) that is sized to extend from the recess to seal against a sealing surface formed by a suction valve seat (not depicted). The multiple references to a same bore **234** is for purposes of ease of description and is not narrowing of the contemplated embodiments of this technology. Whether the recesses defined by surfaces **241**, **243** are formed in the same bore or different bores does not alter the scope of the contemplated embodiments directed to the recess for mounting the seal is formed in the body, and a seal is mounted in the recess and from there seals against a sealing surface of a component in a sealing engagement therebetween.

Similarly, a suction bore **247** is sealed closed by inserting a closure or suction plug or cover **244** defining a sealing surface **245** and securing it in place by advancing a retaining nut **246** in the body **232**, as shown in FIG. **17**. Like the plug **236**, the sealing surface **245** is axially spaced between a first surface **255** and an opposite second surface **261** of the plug **244**. Again, the body **232** in these illustrative embodiments has a surface **248** forming an endless groove or recess intersecting the bore **247** and configured for mounting a seal (not depicted) extending from the recess and sealing against the sealing surface **245** of the suction plug **244**. That transfers the wear from the body **232** to the suction plug **244** in comparison to previously attempted solutions and in accordance with the embodiments of this technology.

The body **232** also forms a plunger opening **250** sized to closely receive a stuffing box sleeve **254** that is sealed in place by advancing a retaining nut **256**, as shown in FIG. **17**. The stuffing box sleeve **254** is characterized by a tubular

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sleeve. The plunger **228** and packing seals **219**, shown in FIG. **9** and FIG. **17**, may be disposed within the stuffing box sleeve **254**.

The opening **250** is formed in part by the plunger bore **252** having a surface **257** defining an endless groove or recess intersecting the bore **252**, into which a seal (not depicted) is mounted in these illustrative embodiments. The suction bore **247** and the plunger bore **252** together form the second conduit. Although these illustrative embodiments use a radial seal, the contemplated embodiments are not so limited. In alternative embodiments other types of constructions are contemplated by this technology employing axial seals, crush seals, and the like.

FIG. **13** is a simplified cross-sectional depiction of the body **232** having the surface **257** forming the recess **258**. Again, the recess **258** intersects the body bore **252** permitting a portion including an outer radial surface of a radial seal **260** to be mounted in the recess **258**. Another portion of the seal **260** not mounted in the recess **258** extends from the recess **258** to pressingly seal against the sealing surface **259** of the sleeve **254**. Although in these depicted embodiments a radial seal is used, the contemplated embodiments are not so limited. The skilled artisan readily understands that other types of seals could be used instead of or in addition to the radial seal depicted, such as axial seals, crush seals, and the like.

FIG. **14** depicts a number of additional endless grooves or recesses in the body **232** for mounting various seals to transfer the wear away from the body **232** to the mating component in accordance with embodiments of this technology. For example, the body **232** has a surface **266** defining a recess **273** intersecting the body bore that defines the discharge opening **235**. Consistent with this whole description, this permits mounting an axial seal **268** (not depicted in FIG. **14**, see FIG. **15**) in the recess **273**, the seal **268** configured to extend from the recess **273** to seal against a leading face of the discharge plug **236** (FIG. **11**). FIG. **15** is a simplified enlarged depiction of the body **232** having a surface **266** defining the recess **273** into which an axial seal **268** is mounted. In these illustrative embodiments the seal **268** is configured to extend beyond the body bore defining the discharge opening **235** to seal against the discharge plug **236** as it is urged downward by advancing the retaining nut **238** (FIG. **11**).

Importantly, the simplified seal construction depicted in FIG. **15** and elsewhere is in no way limiting of the contemplated embodiments and scope of the claimed technology. In alternative embodiments a radial seal or a crush seal and the like can be employed to transfer the erosion wear from the body **232** to the mating component. A crush seal refers to a seal construction that acts at least to some degree both axially and radially. For example, surface **272**, shown in FIG. **14**, forms a recessed corner having two walls that extend concentrically around the bore **252** (FIG. **11**). The stuffing box sleeve **254** may be formed to have side walls that fully overlie the corner section formed by surface **272** when it is positioned in the bore **252**. This allows the seal to act as a crush seal because it seals axially and radially against the sleeve **254**.

Returning to FIG. **14**, the body **232** can have other surfaces forming endless grooves or recesses for mounting various other seals. For example, surface **270** forms a recess for mounting a seal that is configured to seal against a sealing surface of a suction plug (not depicted), like in FIG. **15**. In the same way the body **232** can have surfaces **272**, **274**, **276** forming recesses for mounting seals that are configured to seal against sealing surfaces of the stuffing box

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sleeve **254** (FIG. **11**), the discharge valve seat (not depicted), and the suction valve seat (not depicted), respectively. Likewise, the body **232** can have a surface **278** forming a recess for mounting a seal that is configured to seal against a suction manifold (not depicted). What's common in any event is the seal construction of this technology transfers the seal wear from the body **232** to the less complex and less expensive mating component that is attached to the body **232**.

FIG. **16** depicts the stuffing box sleeve **254** (FIG. **11**) inserted into the plunger opening **250** so that a seal **260** mounted in the recess **258** formed by the surface **257** extends from that recess **258** and seals against the sealing surface **259** defined by the stuffing box sleeve **254**. As the stuffing box sleeve **254** is inserted into this position air pressure forms in a space defined in the clearance gap between the outer diameter of the stuffing box sleeve **254** and the body bore defining the plunger opening **250** and between the seal **260** and a seal **286** at an opposing end of the stuffing box sleeve **254**. The air pressure exerts a force urging the stuffing box sleeve **254** out of the plunger opening **250**, complicating manufacture and degrading the seal integrity at the lower end of the stuffing box sleeve **254**. A breather opening **284** can be formed between that space and ambient space above the stuffing box sleeve **254** to vent the air pressure.

FIG. **16** also depicts a conventional construction of the seal **286** that is mounted in a recess formed by the stuffing box sleeve **254** and extends from that recess to seal against the body bore defining the plunger opening **250**. The contemplated embodiments can include combinations of the conventional construction and the construction of this technology where other matters come into play. For example, without limitation, it can be feasible to use a stuffing box sleeve **254** depicted in FIG. **16** if it can be manufactured or otherwise acquired less expensively than providing the recess instead in the body **232**, and if the particular seal location is one that is not necessarily critical in its role for the overall design for maintaining the highly-pressurized fluid in the flow passage.

FIG. **16** also depicts employing the open-cylinder-shaped stuffing box sleeve **254** and securing it in place by advancing the retaining nut **256** (FIG. **11**). That construction is illustrative and in no way limiting of the contemplated technology. Other configurations can be employed as well. For example, the skilled artisan understands that a conventional stuffing box can be employed that combines the stuffing box sleeve **254** and the retaining nut **256**, unitarily, into one component that has a recess for supporting a seal configured to seal against the body bore defining the plunger opening **235**. In other conventional constructions a stuffing box without that recess is used in combination with a seal carrier insert that mates with the stuffing box and provides the recess for mounting the seal. In yet other contemplated embodiments the stuffing box sleeve **254** can be modified to a construction combining a substantially cylindrical-shaped stuffing box to which is mated a seal surface insert that provides the sealing surface **259** (FIG. **11**).

Returning momentarily to FIG. **11**, the sleeve **254** also protects the bore **252** from erosion by providing an inner diameter surface **264** against which the stuffing box packing **219** (shown in FIG. **17**) seals. That, again, by design transfers the wear from the body **232** to the less complex and less expensive sleeve **254**.

Summarizing, this technology contemplates a high pressure fluid flow apparatus constructed of a body defining a flow passage, a closure mounted to the body, and a means for sealing between the body and the closure. For purposes of

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this description and meaning of the claims the term "closure" means a component that is attached or otherwise joined to the body to provide a high-pressure fluid seal between the body and the closure. In some embodiments such as the described valve embodiments "closure" encompasses a moving component that is selectively positionable to control the fluid flow through the valve, such as the plug described and other components such as but not limited to a wedge, a clapper, a ball, a segment, and the like. In some embodiments such as the described fluid end embodiments "closure" encompasses nonmoving components joined to the body to seal an opening such as but not limited to the discharge plug, suction plug, discharge valve seat, suction valve seat, stuffing box sleeve, discharge flange, suction manifold, and the like. The term "means for sealing" means the described structures and structural equivalents thereof that mount a seal to a body instead of a mating closure to transfer the wear in comparison to previously attempted solutions from the body to the closure. "Means for sealing" expressly does not encompass previously attempted solutions that mount a seal to the closure to extend therefrom and seal against the body.

The various features and alternative details of construction of the apparatuses described herein for the practice of the present technology will readily occur to the skilled artisan in view of the foregoing discussion, and it is to be understood that even though numerous characteristics and advantages of various embodiments of the present technology have been set forth in the foregoing description, together with details of the structure and function of various embodiments of the technology, this detailed description is illustrative only, and changes may be made in detail, especially in matters of structure and arrangements of parts within the principles of the present technology to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

The invention claimed is:

1. A method of manufacturing the fluid end assembly, comprising:
 - providing a housing having a first conduit extending therethrough, and a second conduit extending therethrough that intersects the first conduit;
 - forming an endless groove in the housing such that the groove surrounds the second conduit;
 - positioning a seal within the groove;
 - installing a tubular sleeve within the second conduit such that at least a portion of the sleeve engages with the seal;
 - installing a plurality of packing seals within the sleeve; and
 - installing a reciprocating plunger at least partially within the sleeve and the plurality of packing seals.
2. The method of claim 1, further comprising:
 - forming the groove such that it has a pair of parallel side walls joined by a base.
3. The method of claim 1, further comprising:
 - forming the groove such that it opens towards a centerline of the second conduit.
4. The method of claim 1, further comprising:
 - installing a plug into the first conduit, in which the plug is sized to fully block fluid flow within the first conduit.
5. The method of claim 1 in which the endless groove is characterized as the first groove, further comprising:
 - forming a second endless groove in the housing such that the groove surrounds the first conduit.

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6. A fluid end assembly, comprising:
 a housing having a first conduit extending therethrough,
 and a second conduit extending therethrough that inter-
 sects the first conduit;
 an endless groove formed in the housing such that the
 groove surrounds the second conduit;
 a seal positioned within the groove;
 a tubular sleeve installed within the second conduit such
 that at least a portion of the sleeve engages with the
 seal; and
 a plurality of packing seals disposed within the sleeve;
 and
 a reciprocating plunger disposed at least partially within
 the sleeve and the plurality of packing seals.
7. The fluid end assembly of claim 6, further comprising:
 a closure element installed within the first conduit.
8. The fluid end assembly of claim 7 in which the closure
 element is a plug sized to fully block fluid flow within the
 first conduit.
9. The fluid end assembly of claim 6 in which the first
 conduit is orthogonal to the second conduit.
10. The fluid end assembly of claim 6 in which the groove
 is characterized by a pair of parallel side walls joined by a
 base.
11. The fluid end assembly of claim 10 in which the seal
 engages the side walls and the base of the groove.
12. The fluid end assembly of claim 6 in which the groove
 opens towards a centerline of the second conduit.
13. The fluid end assembly of claim 6 in which at least a
 portion of the housing is configured to contain a fluid having
 a pressure of at least 8,000 pounds per square inch.
14. The fluid end assembly of claim 6 in which the
 plunger is configured to engage with an engine having a
 power output of at least 2,250 horsepower.
15. The fluid end assembly of claim 6 in which the endless
 groove is characterized as the first groove, and further
 comprising:

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- a second endless groove formed in the housing such that
 the second groove surrounds the first conduit.
16. The fluid end assembly of claim 15 in which the seal
 is characterized as the first seal, and further comprising:
 a second seal positioned with the second groove.
17. The fluid end assembly of claim 6, further comprising:
 a valve positioned with the first conduit.
18. The fluid end assembly of claim 6 in which the second
 conduit has a first and second section, and in which the
 endless groove is characterized as the first groove and is
 formed in the first section of the second conduit, and further
 comprising:
 a second endless groove formed in the housing such that
 the second groove surrounds the second section of the
 second conduit.
19. The fluid end assembly of claim 18 in which the seal
 is characterized as the first seal, and further comprising:
 a second seal positioned within the second groove.
20. A system, comprising:
 the fluid end assembly of claim 6; and
 a fluid having a pressure of at least 8,000 pounds per
 square inch within at least a portion of the internal
 chamber.
21. A system, comprising:
 the fluid end assembly of claim 6; and
 an engine engaged with the plunger and having a power
 output of at least 2,250 horsepower.
22. The fluid end assembly of claim 6 in which the sleeve
 has an inner surface and an opposed outer surface, in which
 the plurality of packing seals are engaged with the inner
 surface of the sleeve.
23. The fluid end assembly of claim 22 in which the seal
 is engaged with the outer surface of the sleeve.
24. The fluid end assembly of claim 6 in which the sleeve
 is of single piece construction.

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